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work the concentration of the agent and the length of treatment should be studied in greater detail.

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CONCERNING A MORPHOLOGICAL PREDICTION FROM DISTRIBUTIONAL DATA AND ITS SUBSEQUENT VERIFICATION¹

ALL species of the genus *Salpa* are notable for their two alternating generations. One, known as the "solitary" generation, produces offspring by budding and the buds, when fully mature, constitute what is known as the "aggregate" generation, or, as I shall call them, *zooids*. Each zooid produces, sexually, one of the solitary generation, the embryo being nourished and carried within the body of the zooid until after it has begun to form zooids of the succeeding generation.

The relation between the two generations, however, is not simple; and as there seems to be a widespread misconception regarding this relation, it is well to correct it.

One sees the statement in much of the literature that the solitary generation is asexual, that the aggregate generation is sexual (hermaphroditic), and that the developing embryo of the solitary form is carried within the body of its mother. Such, however, is not the case; Brooks having clearly demonstrated in his classical volume "*The Genus Salpa*," that the solitary form is, in the most literal sense, a female while the zooid it produces by budding is a male. In brief, the curious sexual relationships are as follows:

The solitary form, or female, produces immature males by budding, within the body of each of which the mother tucks away one fully developed and ripened egg together with its follicle. Before fertilization the egg is suspended by means of a fertilizing duct, which opens into the cloaca, into one of the blood channels of the newly formed zooid. The spermatozoa which are drawn into the pharynx of the zooid with the sea-water, are swept past this opening by the contraction of the muscles in swimming, and some of them enter, one of which penetrates to the egg and fertilizes it. The embryo, at an early stage, pushes into the

¹ A paper read before the Western Society of Naturalists, Friday, April 6, 1917, at Stanford University.

cloaca, carrying its wall before it, thus becoming inclosed in an epithelial capsule. This capsule is soon cast off and, in its place, a placenta is formed which, communicating with the blood-channels of the zooid, nourishes the growing embryo until birth. While the embryo projects into the cloaca it is not, at first, exposed to the water, but is enclosed by an epithelial capsule and, after its disappearance, by an embryo sac resembling somewhat the amnion of vertebrates. Later, but still while very young, this sac is distended and finally broken by the growing embryo and from then until birth, the embryo is directly exposed to the water in the cloaca, being fastened to the zooid only by the placenta and a narrow band of ectoderm which connects the neck of the placenta to the walls of the cloaca. After the embryo has reached maturity and made its escape into the water, the testis matures and the zooid becomes a fully developed male. Virtually, then, the mother salpa gives rise, by budding, to its sons; and each son serves first as a depository for one of its mother's unfertilized eggs, then as a living incubator within which its mother's daughter is housed and reared, and lastly as a father. Such is, in brief, the life-cycle of the *Salpæ*.

In *Salpa democratica*, to which the distributional data to follow relate, and which is the tiniest of all the *Salpæ*, the mechanism of budding is as follows: Within the body of the solitary salpa, at its caudo-ventral extremity, lies a compact intestinal tract called the nucleus. Closely associated with it is an organ, "the proliferous stolon," which by segmenting distally gives rise to the zooids. The zooids are budded off rapidly and no evidence is at hand that the stolon ever exhausts its capacity to produce them. The zooids remain attached to each other and to the stolon in the form of a chain and, as segmentation advances, they become crowded and pushed along a spiral path encircling the nucleus. The stolon undergoes more or less regular periods of segmentation and rest so that the zooids are developed in sets or blocks, all individuals in a single block being of approximately the same size and in the same stage of development. Each block contains from forty to sixty-five zooids, and as there are from three to four blocks present when the distal end of the chain is ready to emerge from the test-cavity to the exterior, the stolon carries in the neighborhood of two hundred zooids at one time.

In other species the chain remains intact and attached to the stolon after, as well as before, the zooids are protruded into the

water, but no evidence of this relative to *S. democratica* is recorded in the literature.

During June and July, 1908 and 1909, thirty surface-net hauls were made in the vicinity of San Diego when the temperature of the water was between 15°.9 and 18°.3 C., and forty-six when it was between 18°.4 and 20°.8 C. Solitary forms were captured in greater numbers per unit volume of water filtered from the warmer water, and zooids from the colder water. But one or more of both solitary forms and zooids were captured from a larger per cent. of these unit volumes in the colder than in the warmer water. This is better shown by the following table:

TABLE SHOWING SURFACE DISTRIBUTION OF *S. democratica* RELATIVE TO WARM AND COLD WATER

Temperature in Centigrade	No. of Hauls	Solitary Forms		Zooids	
		Abund. ¹	Freq. ²	Abund. ¹	Freq. ²
15.9-18.3.....	30	67	92	529	92
18.4-20.8.....	46	160	73	127	80

These data show that, while zooids occurred in greatest numbers in the places they frequented the most as would be expected, solitary forms occurred in greatest numbers in the places they frequented the least, or, to state it differently, they were found most often where they occurred in smallest numbers. What does this apparent paradox mean?

Believing that these relations must have been consequent upon a freak result of chance or random sampling, and discovering that only 9 of the 30 cold-water hauls were made during the night (6 P.M.-6 A.M.) while 33 of the 46 warm-water hauls were made at night, the day hauls and night hauls were separated, and the data concerning each were retabulated with respect to the same two groups of temperatures. The results are given in the table on p. 575.

Be it noted that, although the magnitudes of the differences vary, the directions of the differences are exactly the same as revealed by the data in the above table, *i. e.*, solitary forms are most abundant and least frequent in the warmer water, while zooids are most abundant and most frequent in the colder water.

Still being in the position of an unbeliever, the data were re-

¹ Abundance or number of individuals per unit volume of water filtered.

² Frequency or per cent. of unit volumes containing at least one individual.

tabulated in every practicable manner: first, by eliminating all hauls except those made between 6 and 10 A.M.; second, by eliminating all except those made between 10 A.M. and 2 P.M.; third, by eliminating all except those made between 6 and 10 P.M.; fourth, by eliminating all except those made during June, 1909, and fifth, by eliminating all except those made between June 12 and 30, 1909, and within a distance of approximately half a mile of each other. But, in every case without exception solitary forms were most abundant and least frequent in the warmer water, while zooids were most abundant and most frequent in the colder water. Furthermore, the frequency of solitary forms was found to be usually identical with that of zooids. Finally, the probability of such an identical series of relations being due to the effects of random sampling was computed, and the odds against it were found to be more than 1,600 to 1. Obviously, then, the apparent paradox has a significance. What is it?

DAYLIGHT HAULS (6 A.M.-6 P.M.)

	Hauls	Solitary Forms		Zooids	
		Abund.	Freq.	Abund.	Freq.
Cold water.....	21	73	96	710	96
Warm water.....	13	281	92	158	86

NIGHT HAULS (6 P.M.-6 A.M.)

Cold water.....	9	58	81	220	81
Warm water.....	33	135	63	118	79

Let a solitary form be symbolized by a cork, a zooid by an iron weight, warm water by the surface of the ocean, and cold water by the bottom of the ocean. Flotation is then analogous to accumulation in warm water, and sinking to accumulation in cold water. The problem may then be restated as follows:

Since corks float and iron weights sink, what is the relation between them that necessitates taking some corks from the bottom of the ocean whenever a number of iron weights are taken therefrom, and that necessitates taking some iron weights from the surface whenever a number of corks are taken therefrom?

Stated in this symbolical language, it is obvious that the only feasible answer is that at the time the corks and iron weights were removed from the ocean, they were tied together. Now, if,

by experiment, we find that one cork will barely float say six iron weights, corks with more than this number attached would sink, while those with less attached would float. Moreover, if those corks with more than six weights attached usually outnumbered those with less, while occasionally those with less far outnumbered those with more, then both corks and iron weights would be so distributed with respect to surface and bottom that, while corks in the long run would be obtained in greater numbers from the surface than from the bottom, at least one would be obtained in a greater percentage of bottom than of surface hauls. In other words corks would be most abundant and least frequent on the surface, while iron weights would be most abundant and most frequent on the bottom—the exact parallel of the distribution of the two generations of *S. democratica*.

The conclusion, therefore, seems unescapable that the zooids, after being pushed to the exterior on the proliferating stolon of the solitary salpa, remain attached to each other and to the stolon in the form of a protruding chain.

More positive proof being mandatory, each of the seventy-six hauls were carefully examined but, although certain statistical facts pointed toward the existence of protruding chains, no two zooids were found attached together. But, being convinced against my own prejudice, that such chains were encountered and broken up during the processes of towing and washing the net, hauls of brief duration were made, and in some of them several fragments of chains were discovered. Comparison of the size of these zooids with that of the largest ones found within the test-cavity of the solitary salpa proves them to have remained attached to their progenitor for a considerable period, probably until at least one entire block of zooids had reached the exterior.

The distributional data carry many other significant implications which can not be discussed in this limited time. Suffice it to say that a complete report is now nearly ready for the press and will be published in the Zoological series of the University of California under the title "Differentials in Behavior of the Two Generations of *Salpa democratica* Relative to the Temperature of the Sea."

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